UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service

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INFLUENCE OF LOCALITY OF GROWTH AND SEASON ON THE FIBER AND SPINNING PROPERTIES OF TWO VARIETIES OF COTTON, CROP YEARS OF 1936 and 1937

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INTRODUCTION

In 1935, the U. S. Department of Agriculture, through joint effort of the Bureau of Plant Industry and what is now the Agricultural Marketing Service, began a more intensive and extensive study of the quality of American cotton than heretofore had been undertaken. This was in response to a rather wide realization of the lack of information on the characteristics of cottons produced in this country; of how cottons of special characteristics can be distinguished and recognized; of where they can be found; and of how these characteristics are influenced by variety of cotton, type of soil, climatic conditions, and the like.

In the organization of the study, extensive cooperation of the southern agricultural experiment stations was sought and plans were worked out in detail with them. A systematic plan was adopted. Sixteen different varieties of cotton were selected. They differed widely in staple length as well as in many other respects. In general, they were selected to be representative of the more important commercial types and varieties being grown in the different regions at the time the study was started. Sufficient seed was purchased in a single lot for each variety for 3 years' planting. These lots were purchased from reliable sources, in most cases from the originator or breeder of the variety. The stocks, therefore, were as pure as could be had.

These same 16 varieties were planted in 8 replications at 14 different locations scattered across the rainfall part of the Cotton Belt for the crop years 1935, 1936, and 1937. In 1937, they were planted at an additional station in Texas. The study also includes 7 selected varieties grown at 4 stations in the southwestern irrigated region of the Cotton Belt, several of which varieties are common to the series for the rainfall part of the belt.

The ginning of all the samples, a total of about 6000, was handled by the same persons on the same gin (a small saw gin without cleaning or extracting equipment and without a condenser) and under comparable conditions.

Every effort was made, moreover, to have these and all other operations and handling procedures for the different samples as systematic as possible.

A part of the Regional Variety Study has been financed from funds made available by the Textile Foundation. The various experiment stations grew the cotton under carefully controlled or recorded conditions, and members of theirstaffs, together with members of the staff of the Bureau of Plant Industry, located at various stations in the belt, made the observations, recorded the field data, and collected the samples. The fiber and spinning tests have been made, or are being made, in the laboratories of the Agricultural Marketing Service. All planting, and all cultural, harvesting, ginning, manufacturing, and fiber testing of the different samples have been done under as favorable conditions and as systematically as have been practicable.

As will be at once evident, a tremendous amount of work has been involved in this undertaking. In the case of the agronomic data alone, an enormous number of observations have been collected. So, also, in the case of the fiber and spinning data, literally banks of files have been filled with them. Many more still remain to be collected before the job is complete. After all the data are collected, the large task remains to convert them into suitable measures of properties and to analyse them properly with respect to the contributions of the many variables involved, including those grouped broadly under varieties, soil, weather conditions, etc. Preliminary reports are being worked up as certain portions of the data become available in order that cotton breeders, farmers, manufacturers, and others who are interested may receive the benefits of the study at the earliest possible moment.

Some of the fiber and spinning results for the 16 varieties from 8 of the locations in the rainfall part of the belt were tabulated for the 1935 and 1936 crops, and a preliminary report 1/ was made before the meeting of the American Society of Agronomy at New Orleans in November. These data were presented in chart form. A number of the findings and relationships possess particular interest with respect to certain factors and principles involved in the production of cotton fiber properties and spinning quality. An understanding of the type of analysis that is being undertaken and the kind of information that is being obtained, for the broad study as a whole, can be gained by reference to this mimeographed publication, copies of which are available.

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1/ Campbell, Malcolm E. Preliminary Report of Cotton Spinning and Related Fiber Studies, in Connection With the Regional Variety Series, Crops of 1935 and 1936. Address, meeting, Amer. Soc. Agron., New Orleans, Nov. 23, 1939. U. S. Agr. Mktg. Serv. 26 pp., illus. (Mimeographed.)

THE PROBLEM WITH THE 1937 CROP

In the fall of 1937, when the new cotton began to move into the manufacture of various fabrics for mechanical use - especially of tire cords, - it was soon discovered by many spinners that cottons of a given staple length and grade gave yarns and cords with appreciably lower strength than was the case with corresponding cottons and products for the preceding year, or for the general run of crop years. This at once harked back to their similar experiences with and reaction to the unusual crop year of 1931. Many spinners and buyers for large cotton manufacturing plants were therefore greatly and quite naturally concerned. A number of them promptly communicated with cotton fiber and spinning technologists in the Department of Agriculture to inquire what had happened to the cotton, where they could get normal cotton, how they could recognize the good from the bad, why the usual classification procedure failed to reveal these variabilities and inequalities, and a host of other equally pertinent questions.

These questions are good ones, of course, but they are very, very difficult to answer since they are concerned so intimately with the very baffling and elusive matter of cotton character. The nature and extent of the character problem, its importance and its difficulties, as well as the limitations in the present-day knowledge and techniques, was discussed in a paper presented before a recent meeting of the American Society of Agronomy at New Orleans 2/. The more pertinent technical considerations were presented in an earlier report 3/.

The Department was, of course, not in a position to answer on short notice the specific questions which the spinners and buyers raised in connection with the crops of 1931 and 1937, even though we had considerable observations and data on file. As a matter of fact, our fundamental program was just getting well under way when the difficulty arose in the early 1930's. We were seriously concerned, however, about the findings reported by the manufacturers and the shippers for 1937. Immediately we rearranged certain phases and schedules of our cotton research program, in connection with the Regional Variety Study, in an effort to get certain scientific information on the cause or causes of the trouble, more rapidly than would have been possible if we had followed our regular laboratory schedule. That is, we set up a special test in which two rather widely grown, and more or less representative, cottons, of the crop year 1937, would be selected out of the Regional Variety Series, from 11 different locations in the Cotton Belt, and would be manufactured into yarns and cords ahead of the others in the study. For comparison, representative samples of the same two varieties of cotton, grown at the same 11 locations in 1936, were spun into the same products.

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2/ Webb, Robert W. Nature and Scope of Cotton Fiber, Ginning, and Spinning Researches. Address, meeting, Amer. Soc. Agron., New Orleans, Nov. 22, 1939. U. S. Agr. Mktg. Serv. 24 pp., illus. (Mimeographed.)

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3/ Conrad, Carl M., and Webb, Robert W. The Problem of Character Standardization in American Raw Cotton. U. S. Bur. Agr. Econ., Prelim. Rpt. 19 pp. illus. July 1935. (Mimeographed.)

The remaining portion of this paper summarizes, in a somewhat popular way, the findings of these studies on the two varieties, namely, Missdel 4 and Stoneville 5. The 11 locations where grown were Statesville, N. C., Florence, S. C., Fort Valley, Ga., Prattville, Ala., Knoxville, Tenn., Jackson, Tenn., Stoneville, Miss., upland station at Marianna, Ark., delta station at Marianna, Ark., Baton Rouge, La., and Lubbock, Texas.

INFLUENCE OF CROP YEAR AT DIFFERENT POINTS IN THE COTTON BELT ON VARIOUS FIBER AND YARN PROPERTIES

Cord and Yarn Strength in Relation to Fiber Length

In the cotton manufacturing industry, two of the principal measures of quality are yarn strength and cord strength. Skein strength of various counts of yarn in particular is a routine measure in almost each and every mill. The strength of yarns and cords was, of course, the basis on which the inferiority of the 1937 crop first became evident. Accordingly, in the discussion to follow, strength of the manufactured product will be the principal basis of comparison, even though it is appreciated that other properties also are important.

In figure 1 are shown on the same chart the 23-5-3 tire cord strength, the weighted 22's yarn skein strength, the upper quartile length of the fibers, and an adjusted 22's skein strength. The measures for the different properties are plotted with a continuous line for the 1936 crop and a broken line for the 1937 crop, with the average for all locations indicated at the right-hand side. As will be noted, the measures are plotted for the different locations of growth in the Cotton Belt and the arrangement of locations is in order of descending weighted 22's skein strength for the 1936 crop. The results for both varieties of cotton have been averaged in all cases.

Referring first to the weighted 22's yarn strength, it may be mentioned that the term "weighted" means that the strength of 44's and 60's yarns were taken into account, together with the 22's yarn in arriving at a figure for the sample. It will be noted for 1936 that a high value of 110.3 pounds was obtained, and that this decreases gradually for different stations to 96.7 pounds for Lubbock, Tex. The average was 103.45 and the variation was 13.6 pounds, or 13.2 percent of the average. However, in 1937 the order and magnitude of skein strength was greatly altered. The average weighted yarn strength for 1937 was only 95.16 pounds as compared with 103.45 pounds for 1936, or 8.0 percent weaker. The strength of the 1937 samples was nearly the same as those from the 1936 crop at five of the stations, slightly better at one point, and very noticeably lower at five of the locations. The range of weighted 22's skein strength in 1937 is from 105.6 to 67.1, the enormous amount of 38.5 pounds, or more than 40 percent of the average. Baton Rouge was especially responsible for this large range, the yarn strength here being practically 45 percent below the 1936 figure. We shall be especially concerned as we proceed with the different fiber and yarn properties to see how these differences were brought about by certain influences.

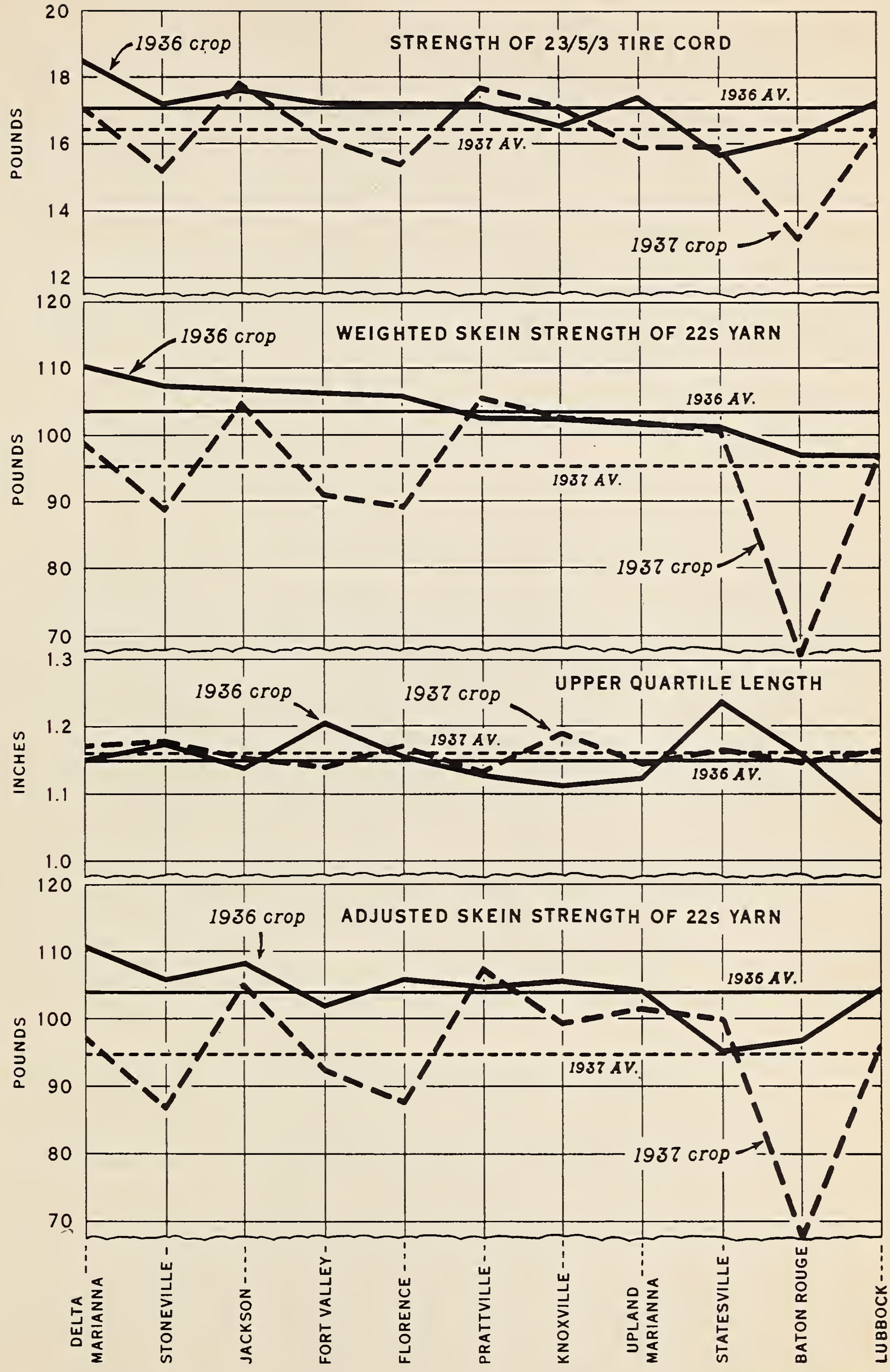

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FIGURE 1.- TIRE CORD AND YARN SKEIN STRENGTH IN RELATION TO UPPER QUARTILE FIBER LENGTH AND YARN SKEIN STRENGTH ADJUSTED FOR A COMMON AVERAGE FIBER LENGTH. EACH PLOTTED POINT IS THE AVERAGE FOR THE TWO VARIETIES.

Turning next to the tire cord strength, shown at the top of the chart, we note that in most respects the curves parallel the corresponding ones for weighted 22's yarn skeins. There are a few slight discrepancies but these are mainly in connection with the 1936 crop. In 1936, the cord strength averaged 17.1 pounds and changed from 18.5 to 15.7. This is a range of 2.8 pounds, or 16.5 percent of the average. In 1937, however, the average was only 16.4 pounds, a 4.1 percent reduction over that for 1936, and the strength varied from 17.8 to 13.2 pounds, a range of 4.6 pounds, or 28.0 percent of the average. Again Baton Rouge, La., is responsible for a large portion of the range. Here the 1937 cord was 18.5 percent weaker than the 1936 cord. One difference between the 1936 curves for yarn and cord strength appears at the two right-hand stations where the cord strength increases, whereas the skein strength decreases. Also, the contrast between the cord strength of the samples for the 2 years at Fort Valley, Ga., and Florence, S. C., was much less than for the skein strength. Since the cord results show, in the main, similar variations to those of the yarn skeins, and since yarn strength seems to be more sensitive to variations in cotton fiber properties than cord strength, the cord strengths will not be considered further in this discussion.

It is a well known fact that yarn skein strength is highly dependent on length of the fiber. Accordingly, one of our first questions will be, to what extent were differences in skein strength due to differences in fiber length. The upper quartile length for the samples here considered is plotted in the third set of curves from the top in figure 1. The upper quartile length is used in preference to the staple length because it is a far more precise measure of length than the latter, and because, on the average, it gives somewhat closely parallel figures. It will be noted, first, that the samples tested for the 1936 crop possessed an average length of 1.15 inches and that those for the 1937 crop, 1.16 inches. Secondly, it will be noted that the samples for the 1936 crop had a much greater range of fiber length than did the 1937 crop. Here the range was from 1.24 inches at Statesville, N. C., to 1.06 inches at Lubbock, Tex., - a difference of nearly 3/16 inch. In 1937 the range was from 1.19 inches at Knoxville, Tenn., to 1.13 inches at Prattville, Ala., - a total of only about 1/16 inch.

Referring back to the weighted 22's skein strength, we may assume that in 1936 the fiber length was a prominent factor in maintaining the level of strength at Fort Valley, Ga., and Statesville, N. C., and in reducing it at Lubbock, Tex. But in 1937 the low strength of yarns and cords at several of the stations can scarcely be ascribed to differences in fiber length. This is better brought out by reference to the lower set of curves where the weighted 22's yarn strength has been adjusted to what it should have been if the fiber length had been the same in all cases as the average for the series. It will be noted that, in comparison to the 1936 unadjusted skein strengths, the figures for Fort Valley, Ga., and Statesville, N. C., have now moved down appreciably and the value for Lubbock, Tex., has moved up quite materially. It would now appear that the reason for the 1936 cord strength increasing at Baton Rouge, La., and at Lubbock, Tex., in contrast to the behavior of the skein strength at these

two stations, was that the cord strength, due probably to the extra twist or cabling effect, was less dependent on fiber length than the skein strength and was more dependent on the ultimate strength of the substance.

On the other hand, in the case of the 1937 skein values, the curves for the unadjusted and adjusted values are of almost the identical form. This is what would be expected, however, since there is such a relatively narrow range of lengths for the different samples of the 1937 series as compared with that for the 1936 series. Accordingly, we must look for fiber properties, over and beyond length, as the source of trouble for the samples from the 1937 crop. Since, in further discussion of the seasonal influence, we wish to examine various other properties, largely of the character category, we shall use only the adjusted skein strength values, so as to eliminate the frequently confusing and overshadowing influence of the fiber-length factor.

Relation of Cotton Grade and Manufacturing Waste to 22's Skein Strength and to Yarn Appearance

It is of interest next to take a look at the grade and waste results for these samples. It is to be anticipated that both factors will be closely related to seasonal influences and an examination of the curves, with respect to these factors, may yield valuable clues as to the cause or causes for the failure of the 1937 crop. The grade of the raw cotton lint and the combined manufacturing picker and card waste are plotted in figure 2 in relation to the adjusted 22's skein strength and the appearance of the 22's yarns. Yarn appearance or evenness is defined in terms of the photographic grade standards for yarn which recently have been developed by the cotton spinning laboratories of the Agricultural Marketing Service and adopted by the American Society for Testing Materials as tentative standards.

Referring, first, to the grades of the samples for the two crops shown in the second set of curves from the top of the chart, it will be noted that the lower grades are indicated by the higher points of the curves and the higher grades by the lower points. The grades varied quite considerably at different growth points for both years. The grade of the 1936 samples averaged 6.11 or slightly below Strict Low Middling, and varied from 5 or Middling to 7.25 or below Low Middling, a range of 2.25 or 37 percent of the average. In 1937 the grade averaged 6.00 or Strict Low Middling, and varied from 4.75, or slightly better than Middling, to 7.50, or between Low Middling and Strict Good Ordinary. The range was 2.75 or 46 percent of the average. Thus, while the average was slightly better, the range of grades was somewhat greater in 1937 than in 1936, and this was probably due to the greater amount of rainy weather after the bolls opened and while the cotton remained on the plant in the field. Only at Florence, S. C., however, was a materially lower grade of the 1937 samples associated with a materially lower yarn strength for this year. At all other stations, except Baton Rouge, La., the grade of the 1937 samples was equal or better than for the 1936 samples. The difference in grade of the samples from Baton Rouge, La., for the 2 years, however, is probably not significant.

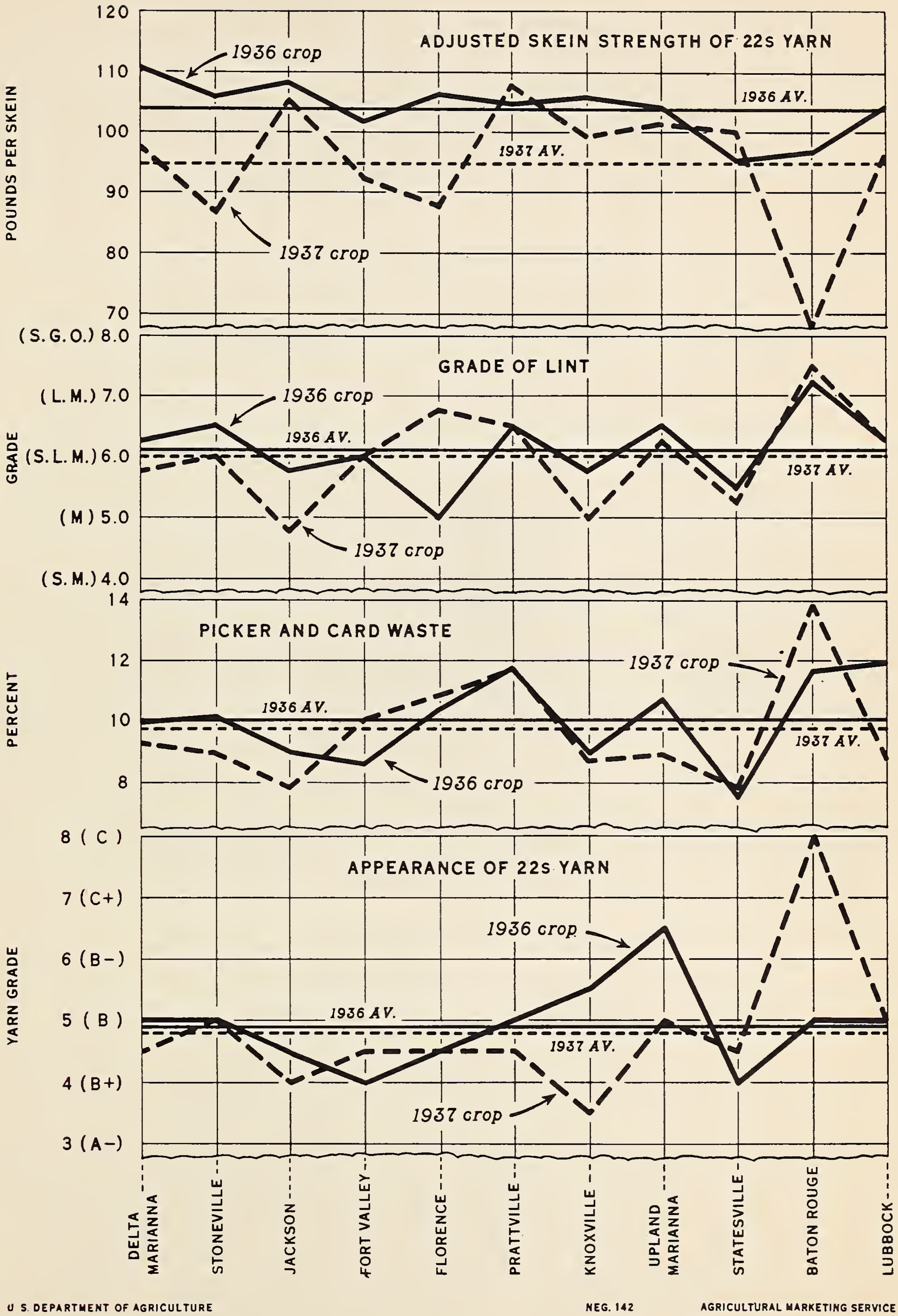

Figure 2.- Adjusted skein strength of 22's yarn in relation to grade of the raw cotton, manufacturing, picker and card waste and the appearance of 22's yarn. Each plotted point is the average for the two varieties.

In general, the course of the curves for grade are almost the reverse of those for the adjusted 22's skein strength. As the grade curves go up the skein strength curves become lower. Thus, there is rather strong circumstantial evidence that, in general, factors which influence the grade also strongly influence the strength of the yarn. It is quite probable that the weathering, either of itself or by its influence on microorganisms, has reduced both the grade and the potential skein strength after the cotton was mature and the open bolls remained on the plants in the field. Especially at Florence, S. C., would this appear to have been the case. Reference will be made again to this point, however, in a later section.

Referring next to the third set of curves from the top of the chart, figure 2, it will be seen that the total manufacturing picker and card waste varied greatly at the different points. For the 1936 samples, the total waste averaged 10.05 percent and varied from a low figure of 7.52 percent at Statesville, N. C., to a high figure of 11.92 percent at Lubbock, Tex., - a difference of 4.4 percent, or nearly 44 percent of the average. In 1937 the total waste averaged 9.70 percent and varied from a low of 7.82 percent at Jackson, Tenn., to a high of 13.82 percent at Baton Rouge, La., a difference of 6.0 percent, or nearly 62 percent of the average. Thus, while the percent waste was slightly lower on the average in 1937 than in 1936, it, like the grade, varied much more in 1937 than in 1936. Furthermore, the percent waste is seen to parallel the grades of the cotton to a very considerable extent, and therefore, in turn, the adjusted strength of 22's yarns. Florence, S. C., and Lubbock, Tex., seem to be somewhat exceptions in 1936, where a relatively high amount of manufacturing waste was associated with rather high grade and high yarn strength. Prattville, Ala., presented an exception in 1937, in that high yarn strength was associated with much waste and low grade of lint.

In three cases with the 1937 samples, higher percent waste is associated with inferior strength for this year. The points are Baton Rouge, La., Fort Valley, Ga., and Florence, S. C., although the effect at the latter point is probably not very significant, statistically.

Turning next to the yarn appearance grades, shown in the lowest set of curves, here again higher figures indicate lower grades. It will be noted that the yarn appearance did not show large differences except at three stations: Knoxville, Tenn., upland station at Marianna, Ark., and Baton Rouge, La. In 1936 the yarn grade averaged 4.9, or about B, and varied from a high of 4.0, or B +, at Fort Valley, Ga., and Statesville, N. C., to a low of 6.5, or between B - and C +, at the upland station at Marianna, Ark. This is a difference of slightly less than a full grade step, or 51 percent of the average. In 1937, however, the grades averaged 4.8, or very slightly better, but varied from a high of 3.5, or between A- and B +, at Knoxville, Tenn., to a low of 8.0, or C, at Baton Rouge, La. This is a range of 4.5, - one and one-half full yarn grades, or 94 percent of the average. At Knoxville, Tenn., and the upland Marianna, Ark., station the yarn grades were appreciably better in 1937 than in 1936, while at Baton Rouge the samples from the 1937 crop gave much lower yarn grades than did the corresponding ones for 1936. At Baton Rouge, the reduced

yarn grade is correlated with greatly reduced skein strength of the yarns at this place for 1937, but at the former two stations the superior grade of the yarn in 1937 is not correlated with a correspondingly higher skein strength.

Yarn Skein Strength in Relation to Fiber Length Variability, Fiber Strength, Fiber Fineness, and Fiber Wall Development

It is not known definitely just how variation of fiber length within a sample affects its yarn strength. It may be presumed, however, that greater variation of fiber length will reduce the drafting efficiency of various manufacturing processes and thus may give rise to a greater variation of yarn count at short intervals along the yarn. Since yarn tends to break at its weakest point, it might be predicted that greater variability of fiber length would tend to lead, on the average, to lower measured yarn strength. In figure 3, second set of curves from the top, this prediction in relation to the adjusted skein strength seems to be realized to a considerable extent, in the case of the 1937 samples, but to little, if any, extent in the case of the 1936 samples. The plotted points are in terms of the coefficient of variation of length, that is, the standard deviation of fiber length expressed as a percent of the mean length.

The coefficient of variation of length for the 1936 samples averaged 27.4 percent and extends from 23.7 percent for Statesville, N. C., to 32.4 percent for the upland station at Marianna, Ark., a difference of 8.7 percent, or about 32 percent of the average. The coefficient of length variation in 1937 averaged 27.2 percent and extended from 23.9 percent at Knoxville, Tenn., to 32.3 percent at Baton Rouge, La., a difference of 8.4 percent, or 31 percent of the average. Thus the average variation and the range were very similar for the 2 years. Only at Baton Rouge, La., and to a somewhat less extent at Florence, S. C., was the length variation appreciably higher in 1937 than in 1936. This might indicate either lower strength of the fibers originally or deterioration with greater gin breakage in 1937 than in 1936. In both these cases greater length variation is correlated with reduced adjusted yarn strength.

Passing to the next lower set of curves in figure 3, it will be noted that the Chandler bundle strength 4/ averaged 77.4 thousands of pounds per square inch for the samples in 1936 and 73.3 thousands for the 1937 samples. This is a decrease of 4.3 thousands of pounds per square inch from the 1936 samples, or 5.6 percent. In 1936 the bundle strength values ranged from a low of 67.7 thousands of pounds per square inch at Statesville, N. C., to a high of 82.5 thousands at the delta station at Marianna, Ark. This is a difference of 14.8 thousands of pounds per square inch, or 19.1 percent of the average. In 1937 the bundle strength varied from a low of 66.0 thousands of pounds per square inch at Baton Rouge, La., to a high of 80.9 thousands of pounds at the upland station at Marianna, Ark. This difference is 24.9 thousands of pounds per square inch, or 34 percent of the 1937 average. In other words, the range in strength for the 1937 samples was more than one and two-thirds times as great as that in 1936.

4/ Richardson, Howard B., Bailey, T. L. W., Jr., and Conrad, Carl M. Methods for the Measurement of Certain Character Properties of Raw Cotton. U.S. Dept. Agr. Tech. Bul. No. 545. 80 pp. illus. 1937. (See pp. 4-35.)

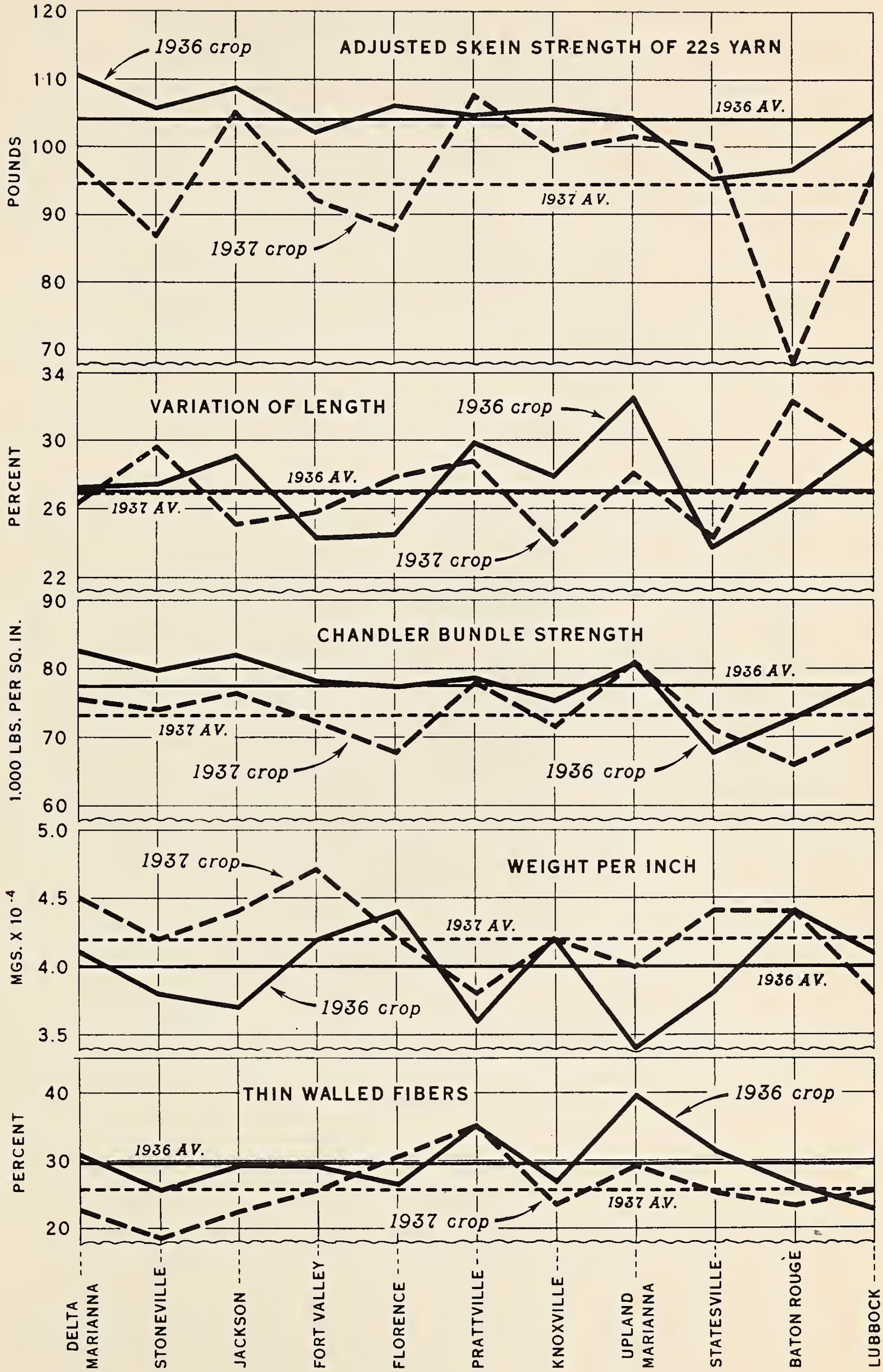

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Figure 3.- Adjusted skein strength of 22's yarn in relation to variation of fiber length, Chandler bundle strength, fiber weight per inch and percent thin-walled fibers. Each plotted point is the average for the two varieties.

The Chandler bundle strength curve for the 1936 samples parallels the 1936 adjusted yarn strength curve fairly well. One slight exception has been observed in connection with the upland station at Marianna, Ark. Also, but to a somewhat less extent, the 1937 Chandler strength curve parallels the 1937 adjusted skein strength curve. In the latter case, however, the magnitudes of the changes in the two curves are not in good proportion, particularly as seen at Stoneville, Miss., Jackson, Tenn., and Baton Rouge, La., in comparison with the other points. It is evident, nevertheless, that the adjusted 22's yarn skein strength reflects the varying strength of the fibers to a rather high degree. That is, in every case where the adjusted yarn strength is lower in 1937 than in 1936, the Chandler bundle strength also is lower in 1937. As will be referred to later, however, various influences were at work at a number of points throughout the Cotton Belt in 1937 to reduce the fiber strength and quality over that shown at the same point in 1936.

The two lower sets of curves in figure 3, representing weight fineness and wall development, respectively, may be conveniently considered together. It will be observed that both the 1936 and 1937 samples varied quite materially in both measures. It is evident that, on the average, the 1937 samples had heavier and coarser fibers than did the 1936 samples, the averages being 4.0 and 4.2 micrograms per inch for 1936 and 1937, respectively. This is a difference of 0.2 micrograms or 4.9 percent of the average. The range extended from 3.8 to 4.7 micrograms per inch, for 1937, as compared with 3.4 to 4.4 micrograms per inch for 1936. The nature of this difference is to be discovered in the wall development curves at the bottom of the chart, which show that the 1937 samples had fewer thin-walled fibers relatively than did those of 1936. The percent in the 1936 samples ranges from 22.8 to 39.8 and averages 29.4 percent, whereas in 1937 the percent ranges from 18.8 to 35.1 and averages 25.7 percent. The difference between the averages is 3.7 percent, or 13 percent of the average. The evidence is for good vegetative growth conditions in 1937, better on the average than in 1936. Slight exceptions must be made in the case of Florence, S. C., and Lubbock, Tex. Neither the fineness curves nor the wall-development curves seem to bear any well-defined relation to the adjusted skein-strength curves. At points they run parallel; at others, in opposite directions. In three of the five cases of large differences between 1936 and 1937 adjusted skein strength, the weight per inch was greater in 1937; in two it was equal or less. It was much greater in three cases where there was little difference in the skein strength for the 2 years. Almost a parallel statement applies for percent immature fibers. This merely indicates, of course, that other fiber properties and factors also are operating and exerting their influences too, sometimes apparently overshadowing the real influence of the fiber property under consideration and frequently making proper interpretations difficult, if not impossible.

Relation of Adjusted 22's Skein Strength to Fiber Cross Section, Lumen Area, and Ratio of Axes

It has always been presumed, and logically, that such fiber-dimensional characteristics as mean cross sectional area, mean lumen or canal area of cross section, and mean ratio of axes of the cross section, would have some relation to yarn strength and other yarn properties. The net area of fiber cross section, that is, the total area within the perimeter of the cross section and exclusive of the area of the lumen, theoretically should be related to the previously discussed fiber weight per inch, if equal density of deposition of the cellulose is assumed. Whether the cellulose is deposited with uniform density in all cases or whether the density varies has been and still is a somewhat disputed point.

The lumen area of the fiber cross section is usually small in relation to the net fibrous substance cross section. This is due, not to the fact that the cotton fiber nearly fills itself with cellulose during the secondary thickening process of growth, but to the fact that the fiber collapses more or less at or near the time of boll opening. The result is, therefore, a fiber in the form of a ribbon-like tube, twisted more or less; that is, convoluted or twisted through angles of 180°, more or less irregularly spaced along the length of the fiber, and with occasional reversals or change in the direction of twist. Sometimes the fibers, on collapsing, do not give rise to ribbon-like structure but to elliptical tubes, with a considerable opening of the lumen compartment remaining. This is true not only in certain cases of underdeveloped fibers, but also in especially thick-walled fibers where the rigidity of the wall structure prevents the complete collapse.

The ratio of axes of the fiber cross section is another measure of maturity. As a rule, a very immature fiber collapses upon drying into a very thin, relatively wide ribbon, and the width of the major axis is several to many times the width of the minor axis. As the fiber develops more and more and cellulose is deposited within the wall this ratio decreases to between 4 and 2, or even less. Accordingly, it is to be expected that the ratio of axes will be fairly well related to percent immature fibers, discussed in the preceding section.

In figure 4 the net area of fiber cross section, the fiber cross section lumen area and the ratio of cross section axes are plotted in relation to the adjusted 22's skein strength. Again the arrangement is by the 2 crop years and 11 locations of growth.

Looking first at the mean net area of fiber cross section, shown in the second set of curves from the top of figure 4, it will be seen that this varied much for both years. The 1936 samples gave an average of 149.5 square microns and those of 1937, an average of 162.2 square microns. This is a difference of 12.7 square microns between the 11 sets of samples.

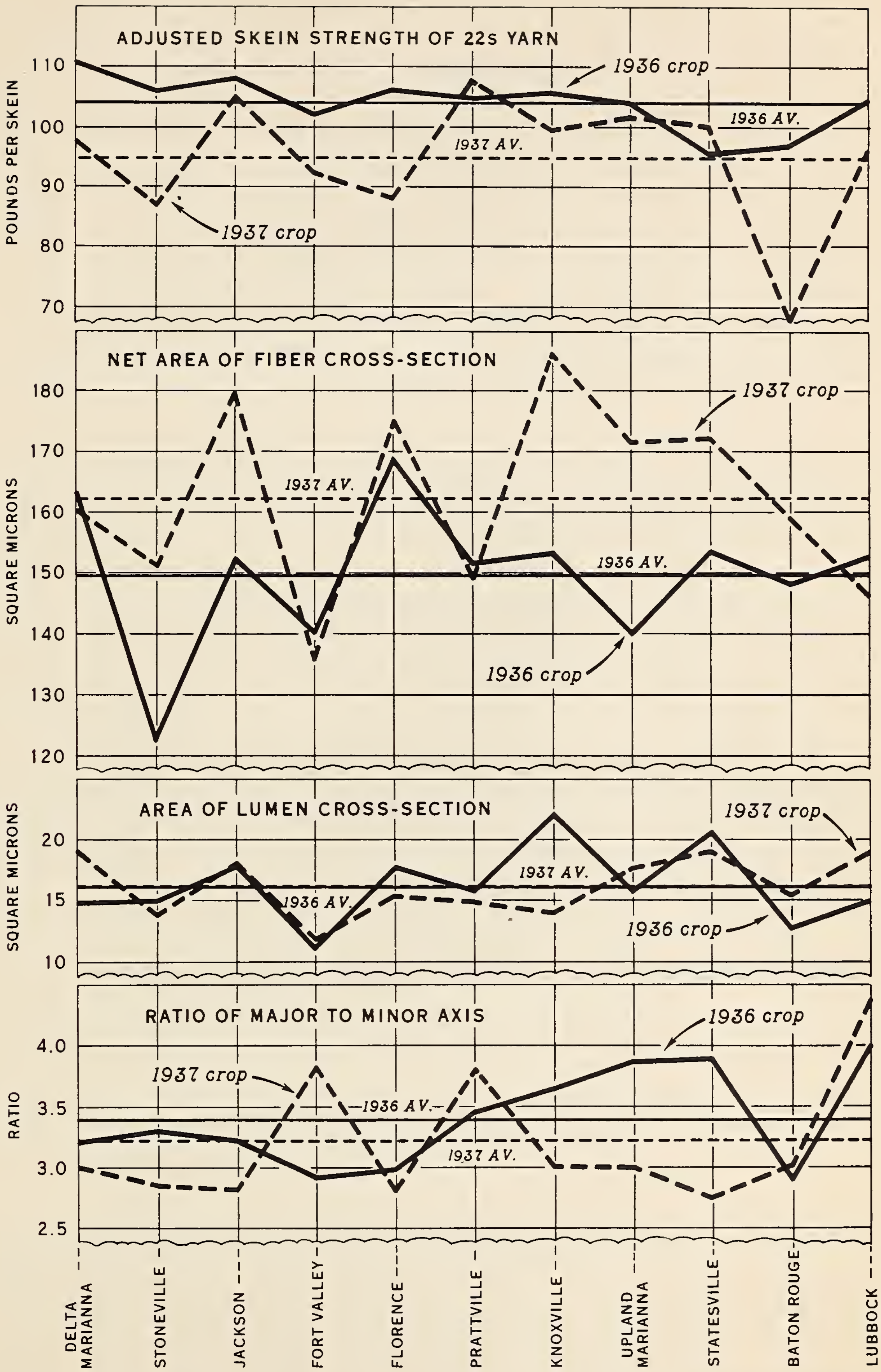

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FIGURE 4.- ADJUSTED SKEIN STRENGTH OF 22'S YARN IN RELATION TO NET AREA OF FIBER CROSS-SECTION, AREA OF LUMEN CROSS-SECTION AND RATIO OF AXES OF FIBER CROSS-SECTION. EACH PLOTTED POINT IS THE AVERAGE FOR THE TWO VARIETIES.

Or, expressed in another way, the 1937 samples possessed fibers which averaged 8.5 percent greater absolute areas of cross sections than did those for the 1936 series. In 1936 the range was from 122.3 square microns at Stoneville, Miss., to 168.3 square microns at Florence, S. C., - a difference of 46.0 square microns, or 30.8 percent of the average. In 1937 the net area of cross section ranged from 135.4 square microns at Fort Valley, Ga., to 186.1 square microns at Knoxville, Tenn., a difference of 50.7 square microns, or 31.5 percent of the average. Thus, for the 1937 samples, the range of absolute fiber cross-sectional areas was greater than that for the 1936 series. This is in agreement with the fiber weight per inch, which, as previously discussed, was greater in 1937 than in 1936. The net area curves show considerable, but by no means perfect, agreement with the weight per inch curves. An especially prominent discrepancy is observed in the case of Fort Valley, Ga., where the weight per inch is moderately high but the net area low. Thus, there is some indication against uniform density with respect to cellulose deposition.

In relation to the adjusted 22's skein strength the net area curves for both years show some parallel and some opposite courses. For the first four stations, reading from the left-hand side of the chart, the trends are completely harmonious. That is, as the net areas increased or decreased, so did the adjusted yarn strengths. In most of the remaining seven cases, however, there is no evident relationship between the two sets of values. Probably the most definite relationship that may be perceived is that the net fiber area was, on the average, larger for the samples in 1937 than for those in 1936, whereas the skein strength was weaker, on the average, in 1937 than in 1936.

The lumen area, shown in the third set of curves from the top of figure 4, also displays considerable fluctuation. The 1936 samples average 16.11 square microns and those of 1937 the same. In 1936, the lumen area varied from a minimum of 11.11 square microns at Fort Valley, Ga., to a maximum of 21.90 square microns at Knoxville, Tenn., a range of 10.79 square microns, or 67 percent of the average. In 1937 the lumen area varied from a minimum of 11.76 square microns, also at Fort Valley, Ga., to a maximum of 18.95 square microns at Statesville, N. C., a range of only 7.19 square microns, or only 44.5 percent of the average. In general, the lumen area seems to fluctuate with the net area, but there are a number of prominent exceptions. No very well-defined relationship is evident between fiber lumen area and adjusted 22's yarn skein strength, or between differences in results for the 2 years.

In the lowest set of curves in figure 4, the ratios of fiber cross-sectional axes also show large fluctuations. The ratio for the 1936 samples averaged 3.39 and for the 1937 samples, 3.22. This gives a difference of 0.17, or the ratio for 1937 is 5.3 percent less than that for 1936. In 1936 the ratio of fiber cross-sectional axes varied from a minimum of 2.89 at Baton Rouge, La., to a maximum of 3.98 at Lubbock, Tex., a range of 1.09, or 32 percent of the average. In 1937 the ratio varied from a minimum of 2.74 at Statesville, N. C., to a maximum of 4.36, also at Lubbock, Tex., - a range of 1.62, or more than 50 percent of the average.

Lubbock, Tex., is remarkable in giving large ratios of cross-sectional axes on both years but apparently this was not detrimental to the yarn strength, whose fluctuations bear little relation to the fluctuations in ratio of axes. The minimum yarn strength from Baton Rouge in 1937 is associated with about an average ratio. The minimum ratio at Statesville, N. C., in 1937, is associated with about an average yarn skein strength. Thus, for these two sets of samples, no well-defined relationship is observable between ratio of axes and adjusted yarn skein strength. It is of particular interest to note that, in comparison with the percent thin-walled fibers, the ratios of the fiber cross-sectional axes show many similar trends; nevertheless, there are a number of exceptions, as might be expected.

Relation of Adjusted 22's Skein Strength to the Structure and Quality of the Cellulose

In a consideration of the sources of failure in most of the samples tested for the 1937 series, the composition and structural arrangement of the fiber should not be overlooked. It is very evident to those who have had to deal with the technology of cotton that the strength of the fiber resides principally in the cellulose constituent. In well matured fiber, the cellulose makes up from 90 to 95 percent of the dry weight, while in less well-developed fibers the percent of cellulose makes up a somewhat lower percentage.

The structural alignment of cotton fibers refers to the cellulose component alone and then, specifically, only to the crystalline portion of this cellulose component. The alignment referred to is measured with an X-ray technique, and may be expressed in terms of degrees, as some function of the average deviation of the long axis of the cellulose crystals with the axis of the fiber. The particular measure that is used in our laboratories is known as the "40 percent angle".

On the other hand, the quality of the cellulose, or its soundness, if you prefer, depends on the length of the cellulose molecules. Good sound cellulose consists, according to our best knowledge, of molecules that are enormously long in comparison to their cross sections. Whether the length differs according to variety of cotton or growth conditions is not known. Those are problems on which technologists in our laboratories are now working hard. We do know in a more or less general way, however, that as a result of exposure to sunlight, dew, rain, and the action of certain microorganisms, the molecules of cellulose of cotton fibers and of many other biological materials are broken into shorter lengths. This occurs as a result of the action of one or several agencies or processes, as follows: (1) direct splitting by the ultra violet component of sunlight; (2) oxidation through combined action of moisture, oxygen of the air, and sunlight; or (3) the digestive enzymes or ferments of microorganisms, which occur generally in almost unbelievable numbers. For example, it has been considered that 3 million microorganism spores per gram of cotton lint are no more than normal, but materially more than this is indicative of overmoist conditions either before picking or in the storage.

The soundness of the cellulose, or the nature and amount of cellulose degradation, may be inferred from the fluidity of the cellulose in cuprammonium solutions, from the solubility of the cellulose in strong alkali solutions, and from the copper number of the cellulose. In figure 5 are plotted the 40 percent angle, the fluidity, the alkali solubility, and the copper number of the cellulose, in relation to the adjusted 22's yarn skein strength. The arrangement of years and stations is as before.

Referring first to the 40 percent angle, it should be stated that larger angles are associated with inferior cellulose and, vice versa, smaller angles with superior cellulose. A special exception must be made, however, in the case of cellulose deteriorated by microorganisms, light, or chemical agents, which cause a shortening of the cellulose molecules without change of their structural alinement. The 1936 samples possessed an average 40 percent angle of 36.4 degrees, whereas the 40 percent angle of the 1937 samples averaged 38.0 degrees. This is an increase of 1.6 degrees for the 1937 samples over the 1936 samples, or 4.4 percent. Roughly, this is equivalent to 4,400 pounds per square inch in terms of Chandler bundle strength. In 1936 the 40 percent angle varied from a low of 33.0 degrees at Jackson, Tenn., to a high of 41.4 degrees at Statesville, N. C., - a difference of 8.4 degrees, or 23 percent of the average. In 1937 the 40 percent angle varied from a low of 34.6 degrees at the upland station of Marianna, Ark., to 40.4 degrees at Knoxville, Tenn., - a range of only 5.8 degrees, or 15 percent of the average. It will be noted that the 40 percent angle for the 1937 samples was generally higher than for those of 1936. This indicates for the cellulose in these samples generally inferior structural arrangement which is in agreement with the observed inferior yarn strength. At only one station, namely, Fort Valley, Ga., is the relation of 40 percent angle for the 2 years out of line with the relation of adjusted skein strength. The apparent discrepancy in relative magnitude of differences of 40 percent angle and adjusted skein strength at Baton Rouge in 1937 will be referred to later.

Looking next at the fluidity of 0.5 percent cuprammonium solutions of the cottons, as shown in the third set of curves from the top of figure 5, it may be mentioned that here also high fluidity is associated with inferior cellulose or cotton and, vice versa, low fluidity is associated with superior cellulose or cotton. The fluidity values average 3.35 rhes for the 1936 samples and 3.26 rhes for the 1937 samples. This is a difference of 0.09 rhe in favor of the 1937 samples, or 2.8 percent. Thus, on the average, the molecules of the cellulose were very slightly longer in the 1937 samples than in the 1936 samples. This was not true at all stations. For example, in 1936, the fluidity varied from a low of 3.14 rhes at Florence, S. C., to a high of 3.83 rhes at the upland station of Marianna, Ark., - a difference of 0.69 rhe, or 20.6 percent of the average. In 1937 the fluidity ranged from a low of 2.84 rhes at Jackson, Tenn., to a high of 3.88 rhes at Baton Rouge, La., - a difference of 1.04 rhes, or 31.9 percent of the average. The range, thus, was considerably greater for the 1937 samples than for those of 1936.

The correlation between fluidity and skein strength is by no means complete. Attention should be called to several points. In 1937 low fluidity of the cotton from Jackson, Tenn., is correlated with high strength for this year, and high fluidity in the cotton from Florence, S. C., and Baton Rouge, La., is correlated with low strength. There seems to be circumstantial evidence of an almost incontrovertible nature that in 1937 the cotton at Baton Rouge, La., was deteriorated mainly, if not entirely, after the bolls opened, probably through the combined action of moisture and microorganisms. This conclusion seems quite probable on the basis of the low grade of the cotton at Baton Rouge for 1937, of the high manufacturing waste, of the low Chandler strength, and of the approximate average structural alinement of the cellulose.

Aside from the good agreement in the instances cited, there are a number of discrepancies in the fluidity - yarn strength relationship. The most notable of these is with the cotton from the upland station of Marianna, Ark., for 1936. Here the fluidity is high but the yarn strength is also rather high. It should be noted, however, that the structural alinement of the cellulose at this station was very good. It is possible therefore that the relatively low 40 percent angle that was obtained was associated with high skein strength and thus kept the values for yarn strength relatively high in spite of the comparative shortness of the cellulose molecules.

The alkali solubility and the copper number shown in the two lower sets of curves, figure 5, may conveniently be considered more or less collectively. As in the case of each of the other measures of cellulose quality shown on this chart, high values are associated with inferior quality and low values with superior quality.

In 1936 the average alkali solubility was 3.72 percent and in 1937, 3.42 percent. Thus, the alkali solubility test confirms the fluidity test in indicating slightly longer molecules on the average in 1937 than in 1936. In 1936 the alkali solubility varied from a low of 3.0 percent at Baton Rouge, La., to a high of 4.66 percent at the upland station of Marianna, Ark., - a difference of 1.66 percent, or 44.6 percent of the average. In 1937 the alkali solubility varied from a low of 3.0 percent at the upland Marianna, Ark., station to a high of 4.02 percent at Prattville, Ala., - a difference of 1.02 percent or 29.8 percent of the average.

The copper number averaged the same in 1937 as in 1936, namely 0.32 percent. In 1936 it varied from a low of 0.23 at Baton Rouge, La., to a high of 0.42 at the upland station of Marianna, Ark., - a difference of 0.19 or 59 percent of the average. In 1937 the copper number varied from a low of 0.24 at Jackson, Tenn., to a high of 0.44 at Knoxville, Tenn., - a difference of 0.20 or 63 percent of the average.

Both alkali solubility and copper number follow the same general trends as the fluidity and accordingly bear about the same relation to the strength of the yarn as does that measure. Both show the relatively

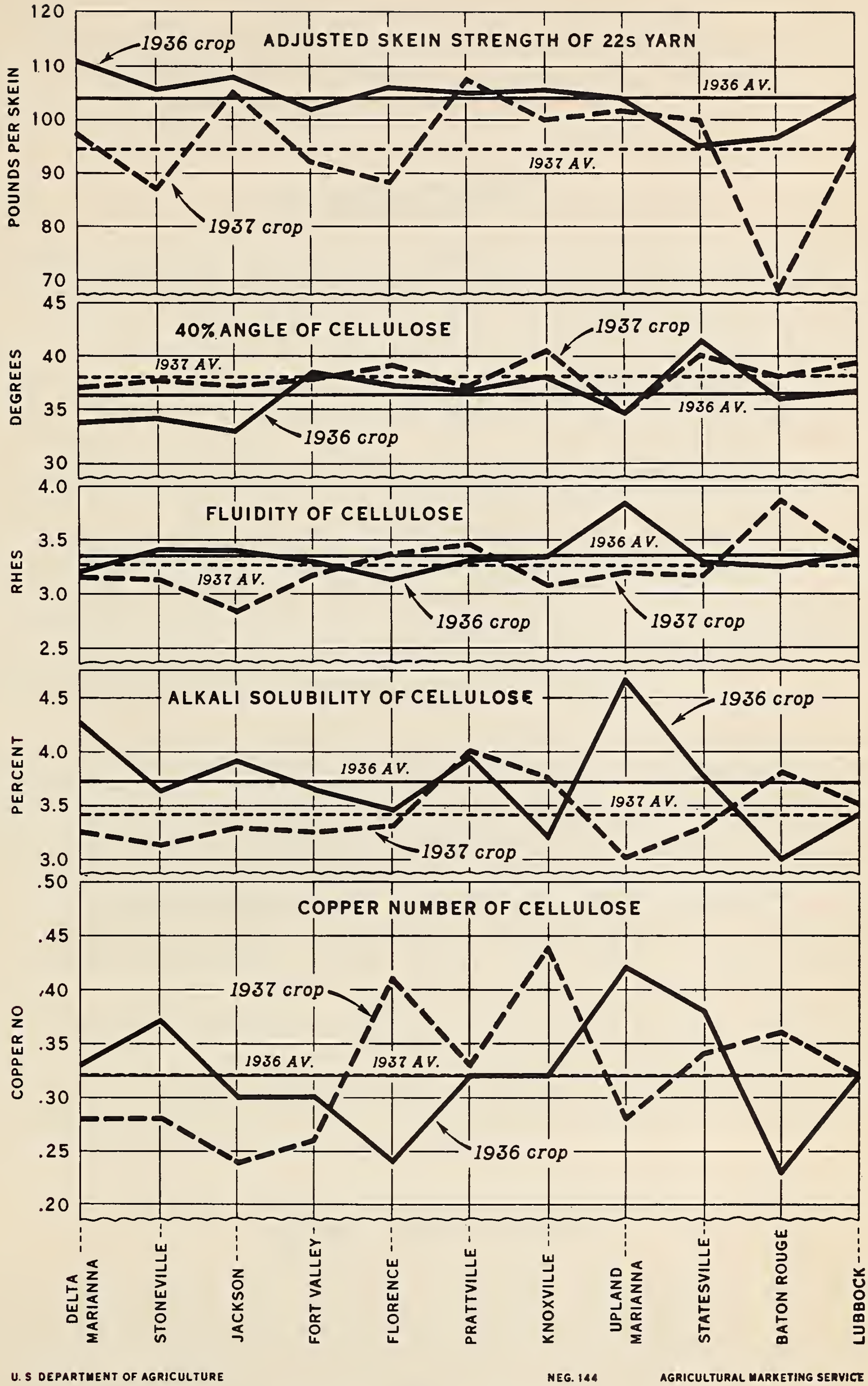

FIGURE 5.- ADJUSTED SKEIN STRENGTH OF 22'S YARN IN RELATION TO THE 40 PERCENT ANGLE, THE FLUIDITY, THE ALKALI SOLUBILITY AND THE COPPER NUMBER OF THE CELLULOSE. EACH PLOTTED POINT IS THE AVERAGE FOR THE TWO VARIETIES.

high degree of deterioration in the 1937 Baton Rouge crop and both show an inferior quality of the cellulose in contrast to the relatively good yarn strength at the upland station at Marianna, Ark., in the 1936 samples. All things considered and in general, however, the quality of the cellulose, both from the standpoint of structural alinement and of composition, tends to be reflected in yarn strength.

VARIETAL DIFFERENCES

Although, in all the preceding discussion, the results for the two varieties, Missdel 4 and Stoneville 5, have been averaged and considered together, it must not be assumed that they necessarily behaved identically in all cases. A discussion of the detailed response of the two varieties to the climatic and soil conditions at the various locations and of the differential influence of their properties on yarn strength is, however, beyond the purpose and scope of this paper. It may be pointed out in passing, nevertheless, that the fiber length of the Missdel samples was rather uniformly almost 1/8 inch longer than that of the Stoneville samples. In spite of this appreciable difference, both varieties gave, at any one location, nearly the same 23-5-3 tire cord strength and nearly the same weighted strength of 22's yarn. When the yarn strength was adjusted to that of a common average fiber length, however, the Stoneville samples gave considerably stronger yarn in all cases than did the Missdel samples, the mean difference being approximately 9.5 percent.

Further examination of the data shows that in general the superior character properties of the Stoneville 5 samples could account for the greater yarn strength obtainable from these samples relative to their fiber length. The Stoneville 5 samples maintained rather uniformly from station to station, better angular alinement of the cellulose, longer cellulose molecules and, upon manufacturing, gave materially less waste. In most cases, the Stoneville samples also gave, in comparison to the Missdel 4 samples, a better appearance grade of the 22's yarn, a lower variation of fiber length, a higher Chandler bundle strength, a greater weight per inch of fiber, a lower percent of thin-walled fibers, a larger lumen and net area of fiber cross section, and a lower ratio of the fiber cross section axes. On the other hand, samples from the two varieties showed rather small and erratic comparative differences with respect to oxidation of the cellulose as indicated by the copper number.

SUMMARY AND CONCLUSIONS

In an attempt to discover the reason or reasons for the relatively poor spinning quality of a considerable portion of American cotton from the 1937 crop, as reported by manufacturers of automobile tire cords, threads, belting, and other so-called mechanical fabrics, a special study was undertaken of the fiber, yarn, and cord properties and the manufacturing waste of different cottons selected from the so-called Regional Variety Series. Two varieties of American upland cotton were chosen for the study:

Missdel 4 and Stoneville 5, and corresponding sets of samples were obtained from the 1937 and 1936 crops. The latter has been used as a basis of comparison, since no unusual manufacturing experiences were occasioned with the 1936 cotton crop, and since its spinning quality proved to be more or less normal or slightly better than average.

The same points of growth, 11 in number, were included for both the 1936 and 1937 seasons. They were widely scattered over the rainfall area of the Cotton Belt, as follows: Statesville, N. C., Florence, S. C., Fort Valley, Ga., Prattville, Ala., Knoxville and Jackson, Tenn., Stoneville, Miss., Baton Rouge, La., the upland and delta stations at Marianna, Ark., and Lubbock, Tex.

Measures of cord, yarn, and fiber properties have been made as follows: strength of 23-5-3 tire cord, weighted skein strength of 22's yarns, adjusted skein strength of 22's yarns, appearance of 22's yarns, manufacturing waste, grade of the raw cotton, upper quartile length of the fiber, variation of fiber length, Chandler bundle strength, fiber weight per inch, percent thin-walled fibers, net area of fiber cross section, net lumen area of cross section, ratio of fiber cross section axes, 40 percent angle of the cellulose, the cuprammonium fluidity of the cellulose, the alkali solubility of the cellulose and the copper number of the cellulose.

By averaging the data for both varieties, the results have been considered, first, with respect to season or crop year and, secondly, in regard to location. The data and relationships are presented in this paper in multiple chart form. While the findings have been analyzed also with respect to variety, by averaging the data for the 2 crop years and for the different locations, the data are not discussed since the varietal phase is beyond the scope of this paper. General reference, however, is made to the varietal relationships that have been observed.

The spinning results for the 2 years showed that on the average the 1937 samples were inferior to those of 1936 by 4.1 percent as regards cord strength, and 6.17 percent as concerns yarn strength. Not all of the samples tested for the 1937 crop were inferior to the corresponding samples for 1936 with respect to yarn and cord strength. That is, at only five of the eleven stations, namely, Florence, S. C., the delta station of Marianna, Ark., Fort Valley, Ga., Baton Rouge, La., and Stoneville, Miss., was the inferiority of yarn strength very noticeable. The most outstanding disparity of all occurred at Baton Rouge, La., where the yarn strength of the 1937 samples was found to be 45 percent weaker than in 1936, and the cord strength, 18.5 percent weaker. On the other hand, six of the stations - Jackson and Knoxville, Tenn., Statesville, N. C., Prattville, Ala., Marianna, Ark., upland, and Lubbock, Tex., - gave approximately the same yarn strength for both years, that at Prattville, Ala., being slightly higher in 1937 than in 1936. Moreover, at two of the stations where the test was made - Knoxville, Tenn., and the upland station of Marianna, Ark. the appearance grades of the yarn were noticeably better in 1937 than in 1936. At Baton Rouge, however, the 22's yarn had a much lower appearance grade than in 1936.

In order to reveal more clearly the effects of the measured properties of the fibers and of the general character of the cotton on yarn strength, the yarn strength data have been "adjusted" for comparison to what they would have been, if all samples had had the same average fiber length and all other properties had been the same as before. With the effects of varying fiber length removed, the yarn results in relation to location remain generally the same but assume different proportions in some particulars; for example, the same five stations mentioned previously continue to show greatly reduced yarn strength for the 1937 samples as compared with that for 1936. Two additional stations, namely, Knoxville, Tenn. and Lubbock, Tex., now show appreciably lower strengths for 1937. The Marianna upland station now shows only slightly reduced yarn strength for 1937. And two of the stations - Statesville, N. C., and Prattville, Ala. - show a slight increase in yarn strength for the 1936 samples over that for the 1937 samples.

The causes for the greatly reduced yarn strength in 1937, as compared with that in 1936, appear to differ at the different stations. At Baton Rouge, La., the extreme inferiority of the cotton seems to be due to fiber deterioration, probably caused principally by microorganisms. In addition to having a somewhat poorer alinement of the cellulose with the fiber axis, the 1937 cotton grown at Baton Rouge, La., had a much higher variability of fiber length than that of the 1936 crop, thereby indicating weaker fibers which broke more during ginning. This is confirmed by the Chandler bundle strength of the 1937 samples at this station, which was considerably lower than that of the 1936 series of samples; and the quality of the cellulose was much inferior as indicated by the fluidity of the cuprammonium solutions, the alkali solubility, and the copper number. At Florence, S. C., the 1937 samples gave similar but much less pronounced evidences of deterioration by microorganisms. The grade of the cotton lint particularly, was nearly two steps lower at this station in 1937 than in 1936. The somewhat high values for cuprammonium fluidity and copper number suggest a poor quality of cellulose, and the low Chandler bundle strength and high length variability indicate poor fiber quality.

At Stoneville, Miss., and the delta station of Marianna, Ark., poor alinement of the cellulose with the fiber axis and coarseness of fiber seems to be the dominant factors associated with the inferior yarn and cord quality of the 1937 samples. The poor cellulose alinement is clearly reflected in reduced bundle strength of the fiber.

On the other hand, at Fort Valley, Ga., the low strength of the 1937 fiber, as indicated by the Chandler bundle test, apparently is not associated with an inferior cellulose angle or deteriorated cellulose. At this station, however, the percentage of manufacturing waste for the 1937 samples was higher and the fibers were coarser and had a larger lumen area than was the case with the 1936 series of samples. Otherwise, there seems to be little explanation at this time for the inferiority of the yarn at the Georgia station in 1937.

Finally, these comparisons reveal the relatively great variability that occurs in cotton quality, not only from season to season, but from place to place within a given season. More important, perhaps, they show how inaccurate and unfair it is to attempt to speak of cotton quality from the standpoint of the crop as a whole, or even of any major section of it, on a basis of data from only a comparatively few tests and locations of growth. It is evident that a careful statistical study of the influence of climatic, soil and other conditions on fiber and yarn properties for the entire Regional Variety Series is needed and such a study will be undertaken as soon as data from the other varieties, locations and years have been assembled.